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None

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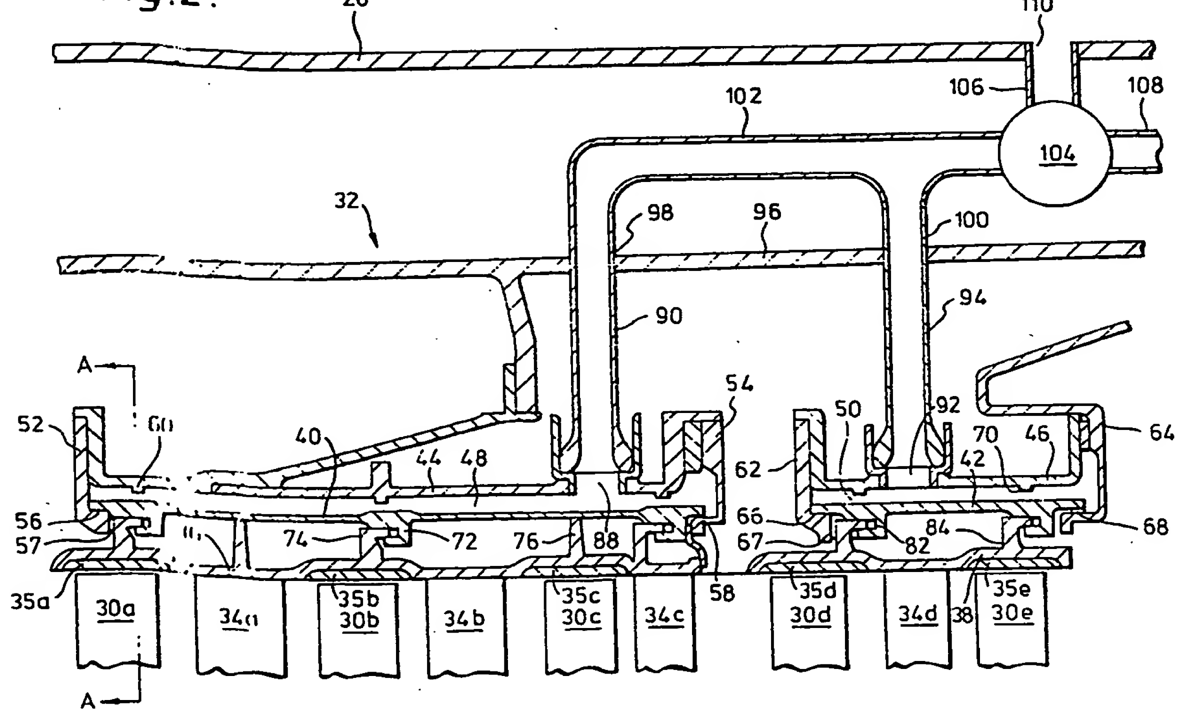
(54) Blade tip clearance control

(57) The invention is concerned with the control of blade tip clearance in the high pressure compressor of a gas turbine engine. The compressor comprises a stator (32) having a cylindrical wall member (40) spaced radially from an inner casing (44) to form a chamber (48). The axial ends of the cylindrical wall member (40) seal with and are moveable radially with respect to the inner casing (44, 52, 54). The casing (44) has radially inner (56) and radially outer stops (60) to limit radial movement of the wall member (40). The wall member (40) carries a ring of shroud segments (36) which are spaced radially from the rotor blades (30). A valve (104) supplies *via* pipes (90, 102, 106, 108) relatively high pressure air from the downstream end of the compressor into the chamber (48) to contract the wall member (40) onto the inner stops (56) and give optimum clearance during cruise, or connects the chamber (48) to relatively low pressure air in the fan duct be aperture (110) in outer casing (26) to allow the wall member to expand to the outer stops (60) to prevent rubbing during transients.

Fig.2.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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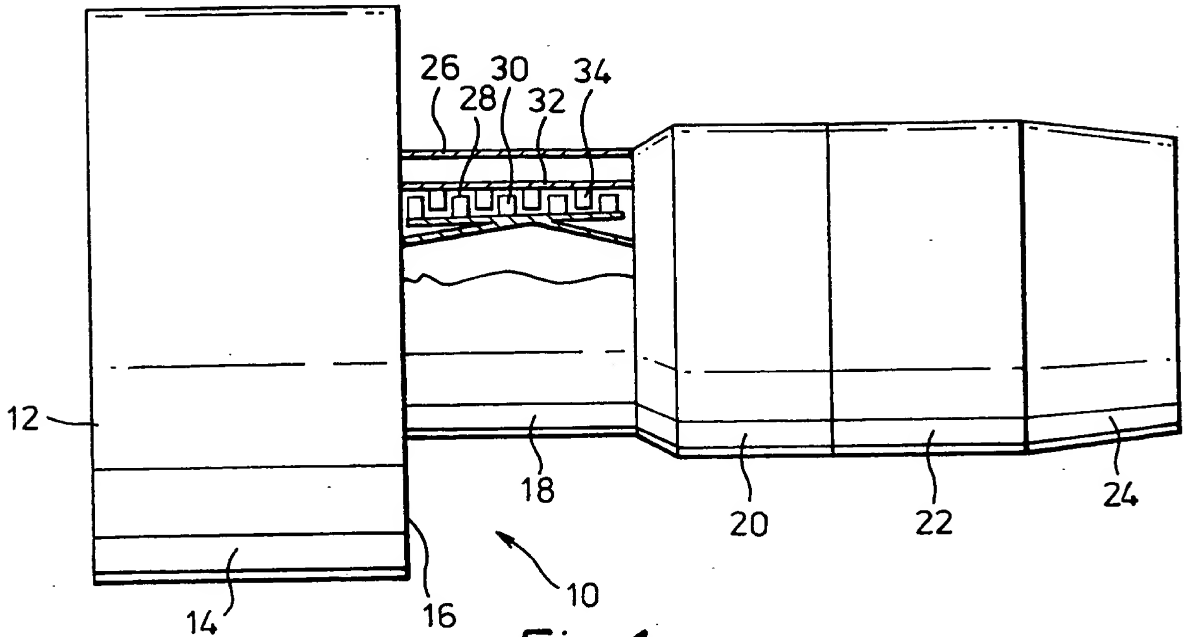

Fig.1.

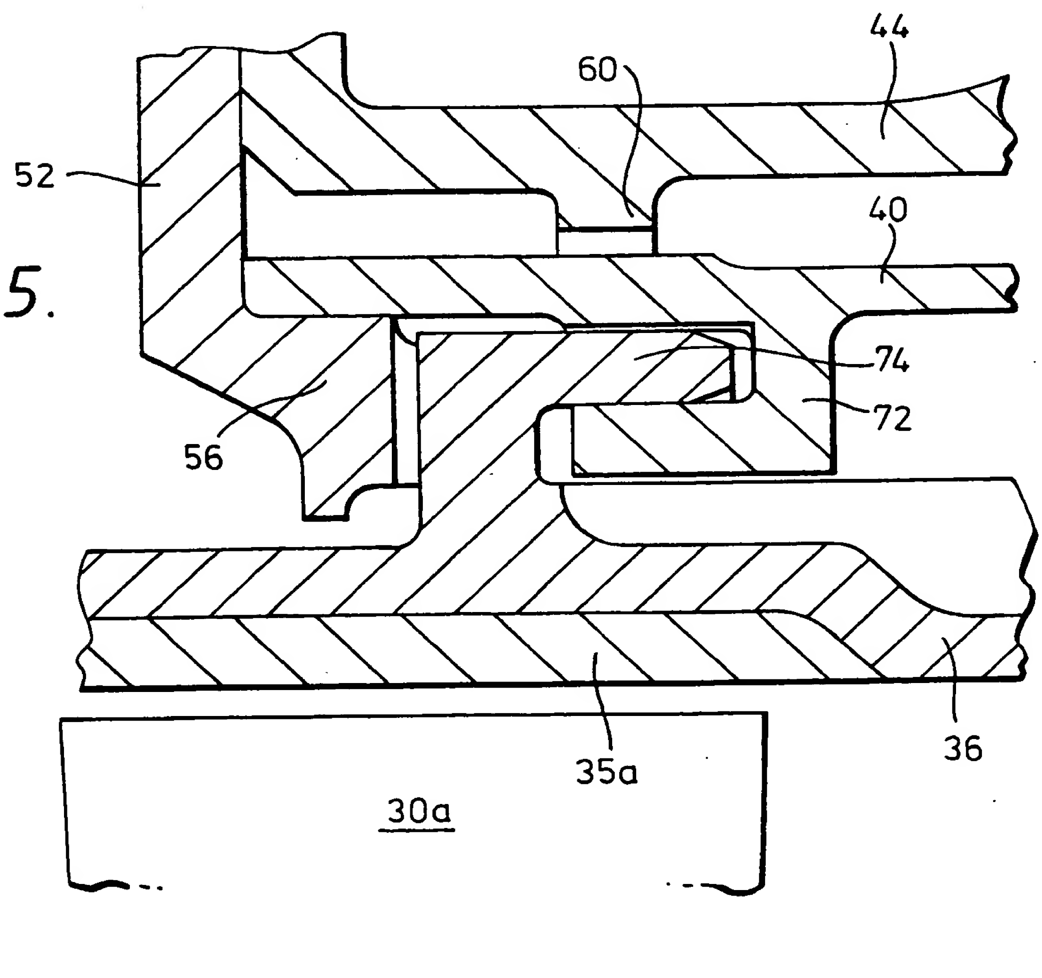

Fig.5.

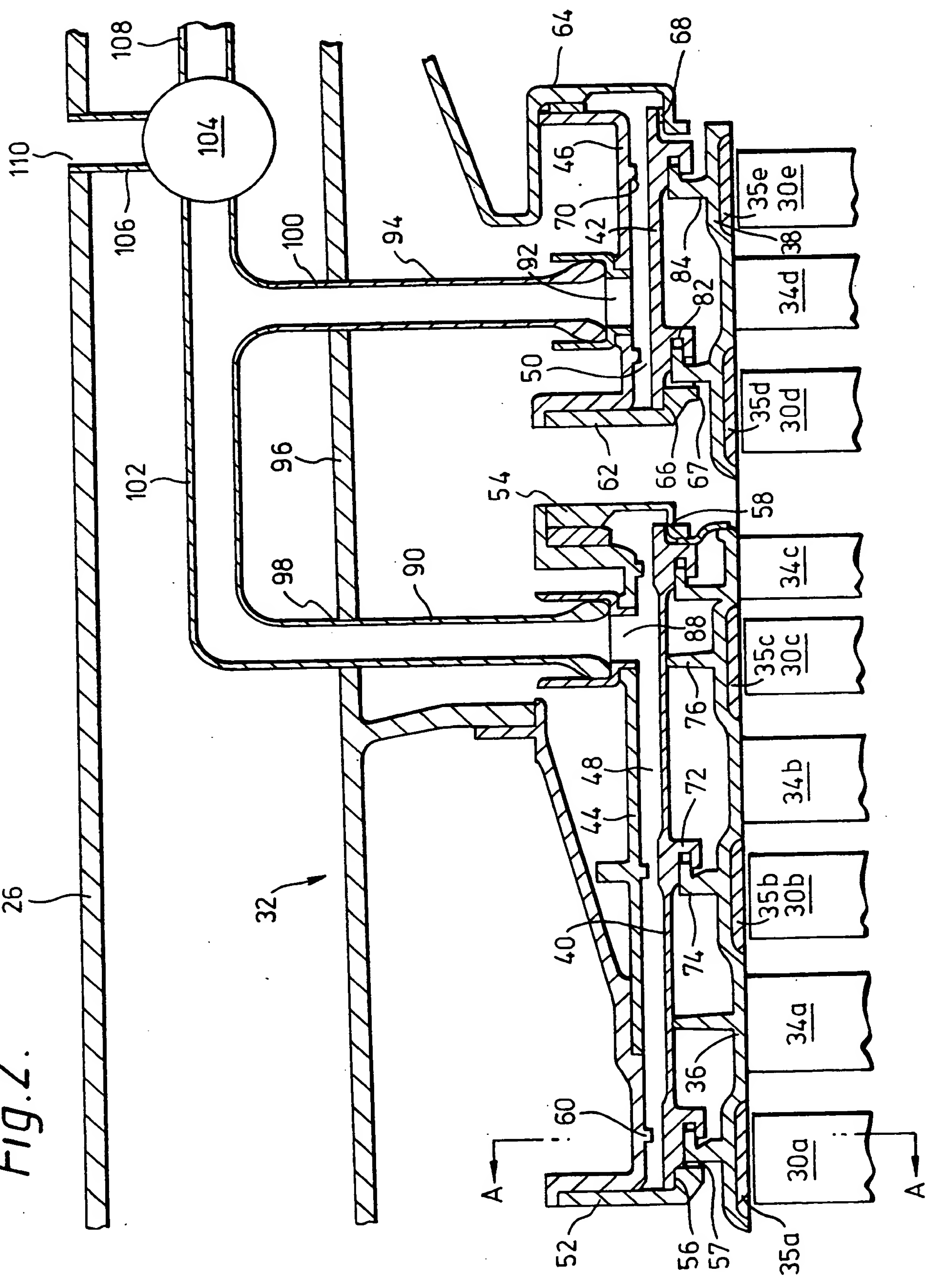
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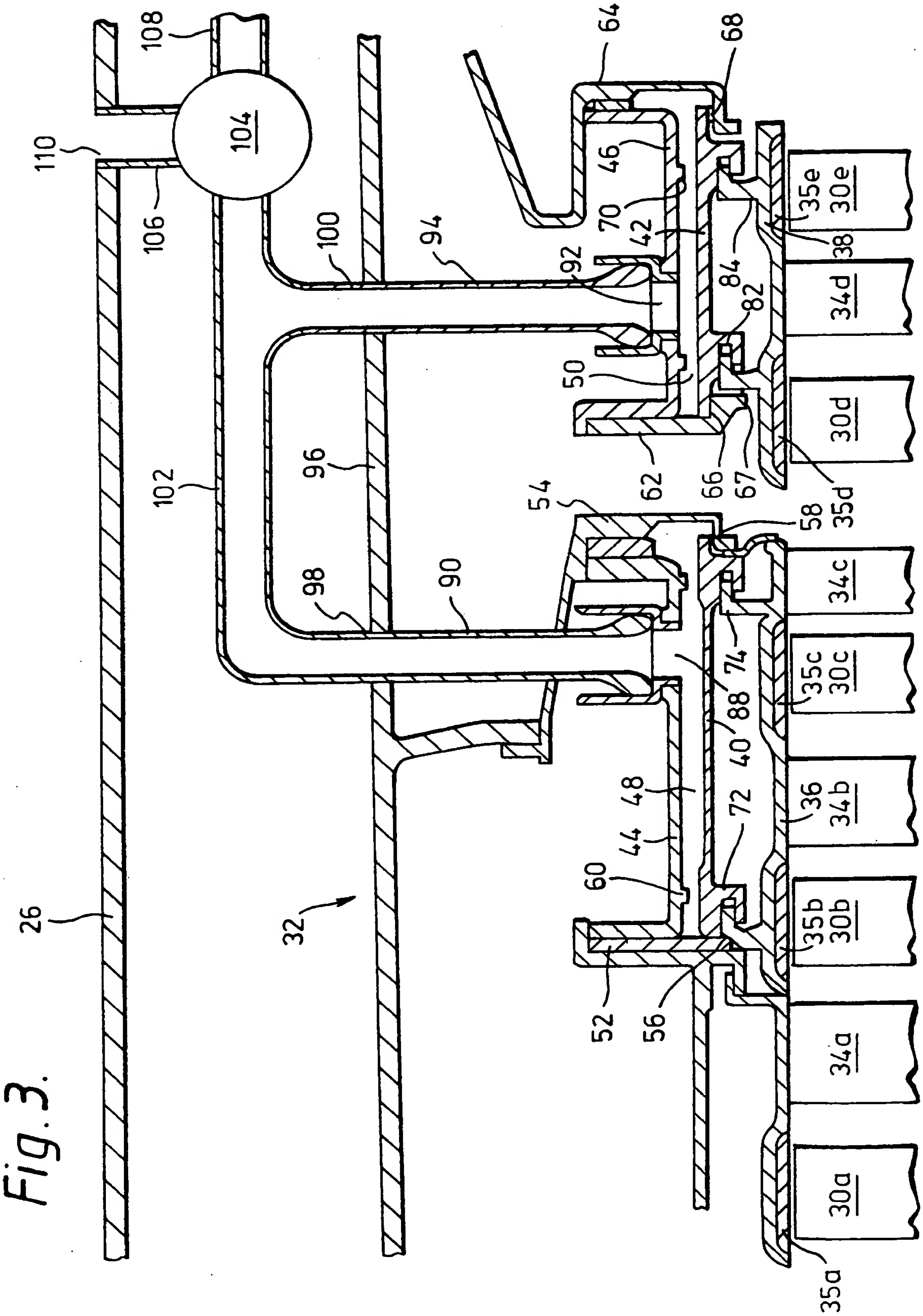
Fig.2.



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35e
30e
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Fig. 3.

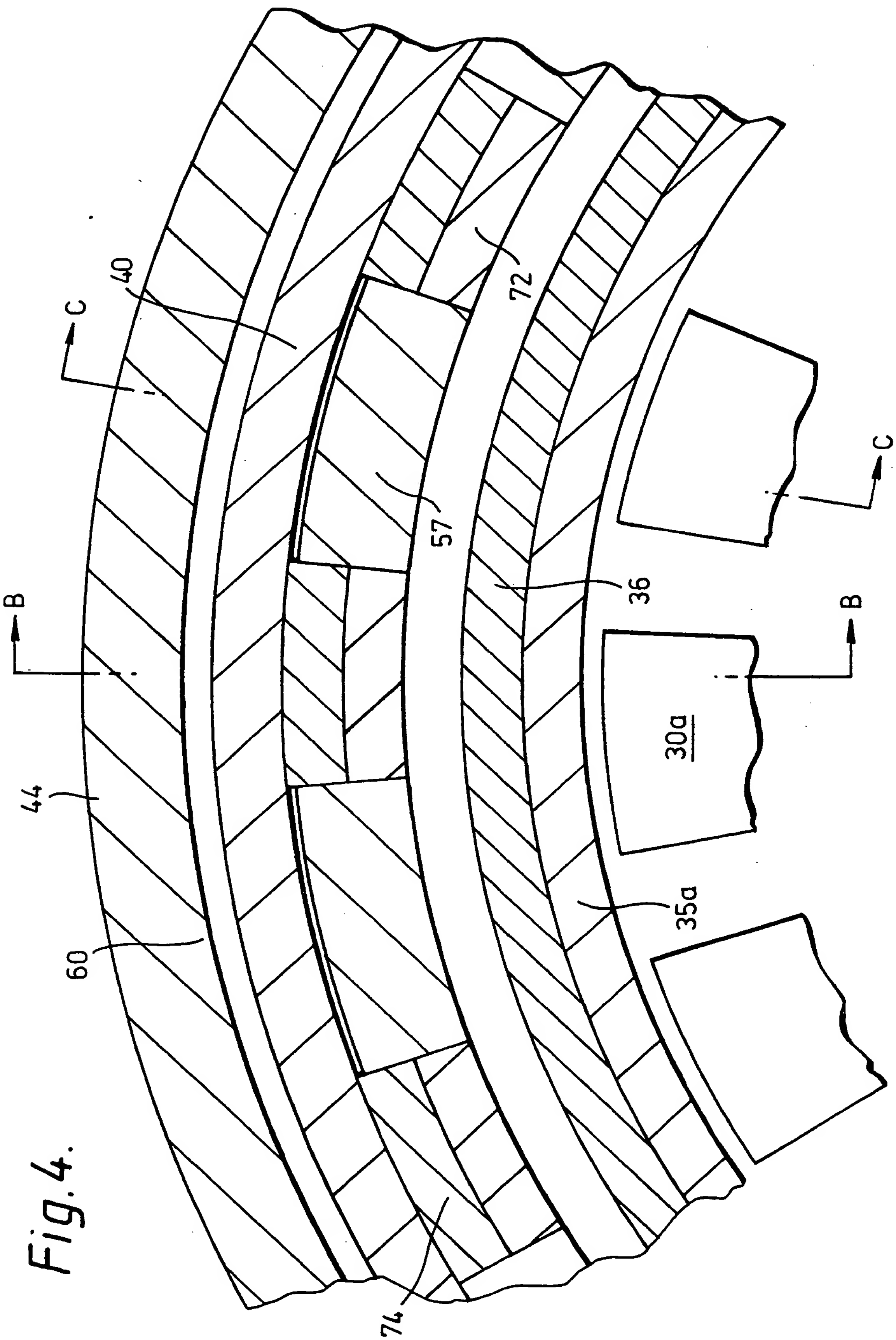
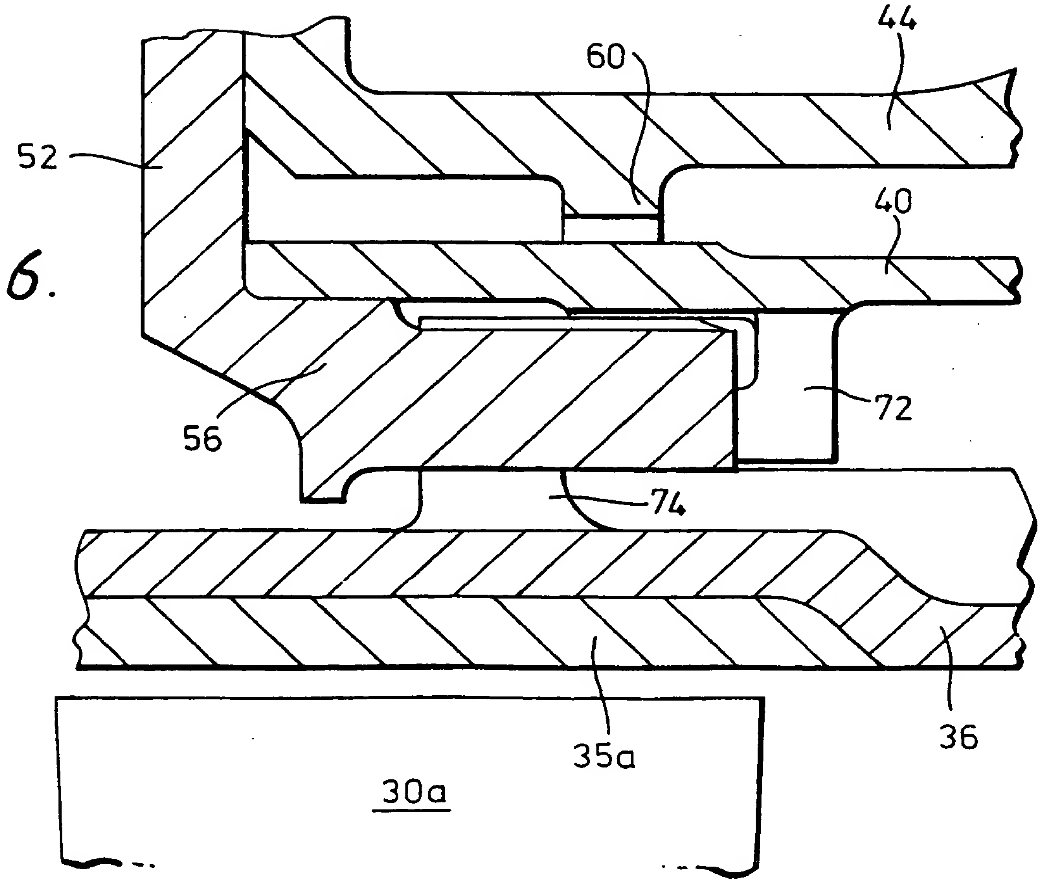


Fig.4.

Fig. 6.



SPECIFICATION

Blade tip clearance control

The present invention relates to blade tip clearance control for gas turbine. This is particularly concerned with the control of blade tip clearance in high pressure compressors of gas turbine engines.

The compressors and turbines of gas turbine engines comprise one or more rotors carrying a plurality of rotor blades and an enclosing stator. The tips of the rotor blades are spaced from shrouds forming part of the stator by a clearance, but during operation of the gas turbine engine this clearance may vary considerably, so as to either cause rubbing between the rotor blades and the shroud or produce a large clearance which reduces the efficiency of the gas turbine engine.

It is desirable to find a method of maintaining as small a clearance as possible between the tips of the rotor blades and the shrouds. It is also desireable to ensure that during engine transients, i.e., during acceleration or deceleration, the blade tips do not rub on the shrouds as this produces increases in the clearance at steady conditions.

In operation a rotor expands due to two causes, firstly the rotor expands due to being rotated at high speeds, i.e, centrifugal force, secondly the rotor expands due to being heated by the working fluid passing through the compressor. The stator, however, is stationary and only expands due to being heated by the working fluid. The expansion of the stator has to be controlled inorder to give a minimum clearance while avoiding rubbing during transients.

The present invention seeks to provide a blade tip clearance control which will provide an optimum clearance between the rotor blades and the shrouds during normal operation of the engine during cruise, and which will maintain an adequate clearance during engine transients to prevent rubbing between the rotor blades and shrouds.

Accordingly the present invention provides, a blade tip clearance control for a compressor of a gas turbine engine comprising a rotor and a stator, the rotor having at least one circumferential arrangement of radially outward extending rotor blades, the stator comprising a casing having an inner surface, a cylindrical wall member being spaced radially from the inner surface of the casing to form a chamber, the axial ends of the cylindrical wall member sealing with the casing but being moveable radially with respect to the casing, the casing having radially inner stops and radially outer stops to limit the radial movement of the cylindrical wall member, a ring of shroud segments being carried from the cylindrical wall member and defining the flow path of the compressor and being spaced radially from the rotor blades by a clearance, means for varying the pressure in the chamber, in operation the chamber being connected to a supply of relatively high pressure fluid to contract the cylindrical wall member radially onto the radially inner stops to give an optimum tip clearance during normal operation of the gas turbine engine, and the chamber being connected to a supply of relatively low pressure fluid during transients of the gas turbine engine to allow the cylindrical wall member to expand radially until it abuts the radially outer stops to maintain an adequate clearance to prevent rubbing between the shroud segments and the rotor blades.

The cylindrical wall member may carry at least one circumferential arrangement of radially inward extending stator vanes, the stator vanes being spaced radially from the rotor by a clearance, the stator vanes being arranged axially alternately with the rotor blades, radial movement of the cylindrical wall member controlling the clearance between the stator vanes and the rotor.

The at least one arrangement of radially inward extending stator vanes may be carried from and may be integral with the shroud segments.

The cylindrical wall member may have at least two axially spaced sets of circumferentially spaced hooks, the shroud segments may have at least two axially spaced sets of circumferentially spaced hooks, the hooks on the cylindrical wall member and shroud segments being engaged/disengaged by relative rotation of the shroud segments and cylindrical wall member.

The radially inner stops may comprise flanges on radially extending walls forming a part of the casing, at least one flange having axially extending fingers which engage in the circumferential spaces between the engaged hooks on the cylindrical wall member and shroud segments to prevent relative rotation of the cylindrical wall member and shroud segments.

The means for varying the pressure in the chamber comprises a valve whhich either supplies relatively high pressure air from the downstream end of the compressor to the chamber *via* a pipe to contract the cylindrial wall member onto the radially inner stops or connects the chamber to relatively low pressure air *via* a pipe and an aperture in an outer casing to expand the cylindrical wall member to the radially outer stops.

The aperture in the outer casing connects the chamber to air in the fan duct or air at atmospheric pressure.

The compressor may be a high pressure compressor.

The present invention will be more fully described by way of reference to the accompanying drawings in which:-

Figure 1 is a partially cut-away view of a gas turbine engine showing a compressor having a blade tip clearance control according to the present invention.

Figure 2 is an enlarged view of the compressor and blade tip clearance control in figure 1.

Figure 3 is an enlarged view of the compressor and an alternative blade tip clearance control in figure 1.

Figure 4 is a section to an enlarge scale along line A-A of figure 2.

Figure 5 is a section along line B-B of figure 4.

Figure 6 is a section along line C-C of figure 4.

Figure 1 shows a gas turbine engine 10 which

comprises in flow series an intake 12, a fan 14, a compressor 18, a combustor 20, a turbine 22 and an exhaust nozzle 24. There is also a fan duct 16. The compressor 18 comprises an outer casing 26 a rotor 28 carrying several axially spaced circumferential arrangements of radially outward extending rotor blades 30. A stator 32 is spaced radially from the rotor blades 30 by a clearance, and the stator 32 carries several axially spaced circumferential arrangements of radially inward extending stator vanes 34. The rotor blades 30 and stator vanes 34 being arranged axially alternately.

The stator 32 is shown more clearly in figure 2, 4, 5 and 6 and comprises an intermediate casing 96 which carries inner casings 44 and 46. Cylindrical wall members 40 and 42 are spaced radially from the inner surfaces of the inner casings 44 and 46 respectively to form chambers 48 and 50 respectively. The inner casing 44 has radial walls 52 and 54 at its axial ends which seal with the axial ends of the cylindrical wall member 40 but allow cylindrical wall member 40 to move radially. The radial walls 52 and 54 have flanges 56 and 58 respectively which extend axially to form radially inner stops upon which the cylindrical wall 40 may rest, and the casing 44 has a number of axially spaced radially outer stops 60 extending from its inner surface.

The cylindrical wall member 40 carries a ring of shroud segments 36, the cylindrical wall member 40 having axially spaced hooks 72 which cooperate with axially spaced hooks 74 on the shroud segments 36. The hooks 72 and 74 are not circumferentially continuous, but are circumferentially spaced on the cylindrical wall member 40 and shroud segments 36 respectively, so that the shroud segments 36 can be inserted axially into the cylindrical wall member 40 and then rotated so that the hooks 72 and 74 engage each other. To prevent rotation of the shroud segments 36, in operation, the flange 56 of the radial wall 52 is provided with axially extending fingers 57 which fit circumferentially between adjacent engaged hooks 72, 74.

The shroud segments 36 have axially spaced shroud portions 35a, 35b and 35c which are spaced radially from the rotor blades 30a, 30b and 30c respectively by a small clearance. The shroud segments 36 also carry stator vanes 34a, 34b and 34c which are positioned axially alternately with the shroud portions 35a, 35b and 35c and which form an integral structure therewith. The shroud segments 36 also have radially extending members 76 positioned intermediate the axially spaced hooks 74 to further support theshroud segments 36 and limit flexing of the cylindrical wall member 40.

The inner casing 44 has an aperture 88 and a pipe 90 fits and seals over the aperture 88 to supply fluid into the chamber 48. The pipe 90 extends through an aperture 98 in the intermediate casing 96 and is connected to a pipe 102. The pipe 102 is connected by a valve 104 to either a pipe 108 which supplies relatively high pressure fluid from the downstream end of the compressor or a pipe 106 which is connected by an aperture 110 in the outer casing 26 to the air at atmospheric pressure or air in the fan duct.

The inner casing 46 has radial walls 62 and 64 at its axial ends which seal with the axial ends of the cylindrical wall member 42 but allow the cylindrical wall member 42 to move radially. The radial walls 62 and 64 have flanges 66 and 68 respectively which extend axially to form radially inner stops upon which the cylindrical wall member 42 may rest, and the casing 46 has a number of axially spaced radially outer stops 70 extending from its inner surface.

The cylindrical wall member 42 also carries a ring of shroud segments 38, the cylindrical wall member 42 having axially spaced hooks 82 which cooperate with axially spaced hooks 84 on the shroud segments 38. The hooks 82 and 84 are circumferentially spaced on the cylindrical wall member 42 and the shroud segments 38 respectively, so that the shroud segments 38 can be inserted axially into the cylindrical wall member 42 and then rotated so that the hooks 82 and 84 interengage. To prevent rotation of the shroud segments 38 the flange 66 of the radial wall 62 is provided with axially extending fingers 67 which fit circumferentially between adjacent engaged hooks 82, 84.

The shroud segments 38 have axially spaced shroud portions 35d and 35e which are spaced radially from the rotor blades 30d and 30e respectively by a small clearance. The shroud segments 38 also carry stator vanes 34d which are positioned axially between the shroud portions 35d and 35e and which form an integral structure therewith.

The inner casing 46 also has an aperture 92 and a pipe 94 fits and seals over the aperture 92 to supply fluid into the chamber 50. The pipe 94 extends through an aperture 100 in the intermediate casing 96 and is also connected to the pipe 102.

In operation the valve 104 allows relatively high pressure fluid to flow from pipe 108 *via* pipes 102 and 90 into chamber 48 and *via* pipes 102 and 94 into chamber 50. The relatively high pressure fluid in the chambers 48 and 50 acts on the cylindrical wall members 40 and 42 respectively causing the cylindrical wall members 40 to 42 to contract radially onto the radially inner stops 56, 58 and 66, 68 respectively to give an optimum clearance between the shroud portions 35a, 35b, 35c, 35d and 35e and the rotor blades 30a, 30b, 30c, 30d and 30e respectively during normal operation of the gas turbine engine i.e., during cruise.

The valve 104 shuts off the supply of relatively high pressure fluid to the chambers 48 and 50, and allows the fluid in the chambers 48 and 50 to flow *via* pipes 90 and 102 and *via* pipes 94 and 102 respectively to and through the valve 104 to the pipe 106 and aperture 110 to atmosphere. Once the fluid in the chambers 48 and 50 is connected to atmospheric pressure the fluid flows to the atmosphere and the pressure in the chambers 48 and 50 reduces allowing the cylindrical wall members 40 and 42 respectively to expand radially under hoop tension until they abut the radially outer stops 60 and 70 respectively to maintain an adequate clearance between the shroud portions and rotor blades

to prevent rubbing during engine transients.

The blade tip clearance control described can produce an improvement in specific fuel consumption (SFC) compared to blade tip clearance control systems of the thermal type ie., those using air or gases bled from the compressor, combustor or turbine to heat or cool the compressor shrouds. The SFC is improved because the present invention uses relatively small amounts of air drawn from the engine to contract the cylindrical wall members by pressure, compared to relatively large amounts of air or gas which are used to heat or cool the shroud continuously in the thermal systems.

Also a simpler pipe system for the air to contract the cylindrical member is required, smaller pipes and fewer in number which reduces complexity and weight.

The present blade tip clearance control has a rapid response rate, once the high pressure fluid in the chambers 48 and 50 is connected to the atmosphere the cylindrical wall members expand immediately to the radially outer stops 60 and 70 respectively.

The radially inner and outer stops can be machined to give precise increases in rotor tip clearance when required, compared to the imprecise thermal system.

The embodiment in figure 3 is similar to that in figure 2 and operates in a similar manner, but the cylindrical wall member 44 carries a ring of shroud segments 36 which have axially spaced shroud portions 35b and 35c, and stator vanes 34b and 34c positioned alternately with the shroud portions to form an integral structure. Shroud 35a and vanes 34a are not carried by the cylindrical wall member. This reduces the axial length of the cylindrical wall member 44 and reduces flexing thereof.

Another advantage of the arrangements shown is that not only are the shroud portions moved radially away from the blades, but also the inner ends of the stator vanes are moved radially away from the rotor to prevent rubbing between the vanes and the rotor.

CLAIMS

1. A blade tip clearance control for a compressor of a gas turbine engine comprising a rotor and a stator, the rotor having at least one circumferential arrangement of radially outward extending rotor blades, the stator comprising a casing having an inner surface, a cylindrical wall member spaced radially from the inner surface of the casing to form a chamber, the axial ends of the cylindrical wall member sealing with the casing but being moveable radially with respect to the casing, the casing having radially inner stops and radially outer stops to limit the radial movement of the cylindrical wall member, a ring of shroud segments being carried from the cylindrical wall member and defining the flow path of the compressor and being spaced radially from the rotor blades by a clearance, means for varying the pressure in the chamber, in operation the chamber being connected to a supply of relatively high pressure fluid to contract the cylindrical wall member radially onto the radially inner stops to give an optimum tip clearance during normal operation of the gas turbine engine, and the chamber being connected to a supply of relatively low pressure fluid during transients of the gas turbine engine to allow the cylindrical wall member to expand radially due to hoop tension until it abuts the radially outer stops to maintain an adequate clearance to prevent rubbing between the shroud segments and the rotor blades.

2. A blade tip clearance control for a compressor of a gas turbine engine as claimed in claim 1 in which the cylindrical wall member carries at least one circumferential arrangement of radially inward extending stator vanes, the stator vanes being spaced radially from the rotor by a clearance, the stator vanes being arranged axially alternately with the rotor blades, radial movement of the cylindrical wall member controlling the clearance between the stator vanes and the rotor.

3. A blade tip clearance control for a compressor of a gas turbine engine as claimed in claim 2 in which the at least one arrangement of radially inward extending stator vanes are carried from and are integral with the shroud segments.

4. A blade tip clearance control for a compressor of a gas turbine engine as claimed in claim 1, 2 or 3 in which the cylindrical wall member has at least two axially spaced sets of circumferentially spaced hooks, the shroud segments having at least two axially spaced sets of circumferentially spaced hooks, the hooks on the cylindrical wall member and shroud segments being engaged/disengaged by relative rotation of the shroud segments and cylindrical wall member.

5. A blade tip clearance control for a compressor of a gas turbine engine as claimed in claim 1 in which the radially inner stops comprise flanges on radially extending walls forming a part of the casing, at least one flange having axially extending fingers which engage in the circumferential spaces between the engaged hooks on the cylindrical wall member and shroud segments to prevent relative rotation of the cylindrical wall member and shroud segments.

6. A blade tip clearance for a compressor of a gas turbine engine as claimed in any of claims 1 to 5 in which the means for varying the pressure in the chamber comprises a valve which either supplies relatively high pressure air from the downstream end of the compressor to the chamber *via* a pipe to contract the cylindrical wall member onto the radially inner stops or connects the chamber to a relatively low pressure air *via* a pipe and an aperture in an outer casing to expand the the cylindrical wall member to the radially outer stops.

7. A blade tip clearance control for a compressor of a gas turbine engine as claimed in claim 6 in which the aperture in the outer casing connects the chamber to air in the fan duct or air at atmospheric pressure.

8. A blade tip clearance control for a compressor of a gas turbine engine as claimed in any of claims 1 to 7 in which the compressor is a high

pressure compressor.

9. A blade tip clearance control for a compressor of a gas turbine engine substantially as herein described with reference to and as shown in the accompanying drawings.

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